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Internal Letter

Rockwell International

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SUBJECT - **Cost Comparison of Drilling Program and a Geophysical Survey**

The current lay-out of bedrock wells does not sufficiently meet the objectives of the remedial investigations. Additional phases of drilling will be needed to adequately characterize the subsurface. This is not to say the proposed well placements are incorrect. The mode of all remedial investigations must be a phased approach. This design allows acquisition and interpretation of additional information and data. The new data are then compared to the existing conceptual model. The model may then be revised and/or additional data gaps identified. When additional data gaps are identified, the next phase of the RI can be scientifically and cost effectively designed. Additional phases are both expensive and time consuming. Due to the geologic characteristics of our RI area, a search for alternate remedial investigation (RI) methods was initiated to avoid excessive costs and time for completion. The method which seems most favorable is high resolution seismic reflection. High resolution seismic reflection is a state-of-the-art technology capable of acquiring detailed subsurface data.

Upon technically evaluating the recently received high resolution seismic reflection proposal it was found necessary to evaluate cost comparisons between the proposed drilling program and the seismic reflection survey. This evaluation begins with the current drilling program approach and predicts what will be needed to fulfill the objectives of the RI program. The costs incurred from past drilling operations are used to predict the costs and time for completion of future RI efforts. The same evaluation is then established for the seismic reflection proposal.

After evaluating the proposed lay-out of bedrock wells for the upcoming Phase II RI, it is obvious that additional drilling phases will be needed in order to fully characterize the bedrock geology and its contamination. For example, sandstone T located, at the west end of the East Trenches, is scheduled to receive four new wells. The areal coverage of these four wells is only in the projected subcropping area of the sandstone. The cross sections of this sandstone is shown to be relatively thick and continuous. Therefore, the extent of the sandstone body and of the contamination must be delineated downgradient as well as along its strike. This holds true for many of the sandstones found so far in the RI area.

The complexity of the geology in this area is the product of a classical fluvial depositional system which makes geologic and hydrogeologic predictions extremely difficult. Rock outcrops along McCaslin Blvd. north of the plant display sandstone channels as small as ten feet wide. Large variations in thicknesses of sandstones over short distances (30 to 40 feet) in the RI area are present. This is typical of fluvial sandstones in general. In order to get a 100 % coverage of the bedrock sandstone units, wells would need to be drilled on 20 foot centers. This obviously would be extremely expensive and time consuming. However, how much confidence/distance can you place on extrapolating between points of a heterogeneous formation ?

The inherent problem with all drilling programs is that information from one borehole is limited. Therefore, one must extrapolate between points in order to gain the information needed. The extent of contamination can not be fully assessed with only a few additional drilling phases when well installations serve multiple objectives (i.e. determination of horizontal and vertical extent of contamination, correlations and extent of sandstones). For example, proposed bedrock wells along strike of sandstone T are 300 and 600 feet to the south and only 50 feet to the north of well 25-87Br. The purpose of these particular well placements is to delineate the width of the sandstone along its strike. However, the edge of the sandstone may easily exists within the 300 foot gaps and even 50 foot gaps. Therefore, unknowns still exist; the extent of contamination, possible zones of high hydraulic conductivities and the orientation of the sandstone bodies. In addition, down-dip investigations need to be just as detailed in order to solve these same questions. It should be noted that contamination does not usually travel as a massive front through the subsurface but as fingers possibly followed by a massive front. If the areas of high hydraulic conductivities can be identified then the possible fingers of contamination can be located.

The current drilling program approach is to continue to drill until the RI objectives are fulfilled. It is difficult to say how many additional phases will be needed to complete the investigations. However, one is assured that there will be several more. The projected costs are based upon several assumptions; the possible extent of the contamination and the continuity of the sandstones. It is assumed that leaking drums were first noted at the 903 Pad around 1964 and the contaminant transport mechanism is solely that of advection, to project the maximum distance of migration. Since the presence of Carbon Tetrachloride is found in sandstone T and its source is assumed to be the 903 Pad, the hydraulic conductivity geometric mean for alluvial slug tests is used (1 x 10 -3 cm/s). This allows five years to reach well 25-87Br. The hydraulic conductivity derived from pump tests are not used because its calculated travel time to reach the subcrop area is 80 years. This infers that carbon tetrachloride would not yet have reached the area.

Once in sandstone T, contamination would travel at a linear velocity of 310 feet per year. This is estimated using the hydraulic conductivity from the slug test of well 25-87Br (2 x 10 -3 cm/s) which is in the subcropping area. Assuming homogenity and continuity of this sandstone, the extent of contamination would be approximately 5,890 feet away from sandstone T's subcropping area, below well 39-86. The depth of the sandstone at this point is roughly 700 feet deep. The geometric mean of bedrock hydraulic conductivities is 8 x 10 -5. This would take into consideration possible variations in bedrock hydraulic conductivities (heterogeneities). The extent of contamination would be much less, roughly 500 feet away from the subcropping area at a depth of approximately 60 feet.

COST ASSUMPTIONS FOR ONLY BEDROCK WELL DRILLING

Drilling and well completion = $53.75/ft.
Average well depth 100 ft.
Estimated 3 days per well.
Cost of geologists = $14.00/hr.
HS&E equipment, well dev.,aquifer testing. amount to $1,550 per well.
Office work ; report writing Fees and Other Direct Costs are not included.

TOTAL COST PER WELL = $7,000 to $8,000

A total of 35 bedrock wells are to be drilled as part of Phase II

COST = $245,000 to $280,000

This does not include analytical cost, $1,200 per sample per well per quarter.

ADDITIONAL PHASES

Assume the coverage to be the same as for the seismic survey for comparative purposes, 12,000 linear feet.

20 foot centers = 600 wells	COST $4.2 million to $4.8 million
60 foot centers = 200 wells	COST $1.4 million to 1.6 million
100 foot centers = 120 wells	COST $840,000 to $960,000

The time frame for installation of these proposed wells would be on the order of six months to years depending on the number of drill rigs used and turn-around-times of analytical services. In my opinion, in order to resolve the bedrock delineation problem, wells will have to be drilled at a maximum 40 to 60 foot centers. This would take a minimum of three years or more to complete, assuming a maximum of 40 wells were installed per year.

A more realistic approach for the comparison is by area. The investigation sites cover an area roughly 4,000 by 1,000 feet. Drilling 100 foot centers, twice the recommended distance, in this area would cost $2.8m to $3.2 m. (a minimum of 400 wells). Wells are sampled quarterly for at least one year in order to characterize seasonal changes. Therefore, analytical services for one year would cost another $1.9 million. The cost increases considerably with decreasing distances between wells.

The initial investment of seismic reflection is much higher, however, the duration of the RI program will be shortened and most likely at a cost savings. There are obvious benefits for using high resolution seismic reflection which are discussed below.

1. The amount of data acquired is equivalent to drilling boreholes every 2 to 4 feet which would cost a minimum of $21 million. Large areal coverage by a seismic survey is more cost effective because the seismic survey covers an area and is not a point source of information such as a borehole or well. This is extremely important for sandstone

correlations and contaminant delineations. The seismic data will progressively become available for new well locations starting approximately 2 months after the field collection starts. This final contract task will take five months to complete with a final report. The entire contract (three tasks) will take no more than eight months to complete.

2. The delineation of the extent of contamination is still required which will require additional phases of drilling. However, the 3-dimensional configuration of the sandstone bodies and possible location of the contamination would be known. Precise locations to drill and depth to drill would now be known before hand. This eliminates surprises and provides the information needed for the most optimum well placements possible for monitoring and clean-up designs while limiting the number of additional drilling phases, monitoring wells and cost of analytical services.

3. The correlation between sandstones and their possible inter-connections and/or cross contamination zones and areas of higher permeability would be better defined. This is important in defining the uppermost aquifer and determining were there is potential contamination. If these are defined, well placements and clean-up designs will be precise.

4. The time frame would be the same as for one drilling phase, approximately 8 months. However, actual field work would be for only one month.

5. The visual impact of having hundreds of well heads sticking out of the ground would not exist and the possible inter-connection between aquifers due to excessive drilling would be eliminated.

6. Sandstones existing under one another would be indicated. As the program now exists, if a sandstone of sufficient thickness is encountered a well is installed. It is unknown if another sandstone exists underneath it and if so, how far below. As indicated above in #3, proper monitoring design and identification of the uppermost aquifer are essential to any RI program and meeting state and federal regulations.

7. The resolution of the data would be 1 to 3 feet vertically and 2 feet horizontally. Therefore, the only extrapolation existing would between the survey lines. However, the extrapolations would be based upon the most comprehensive data possible. The drilling program targets sandstone units with minimum vertical thicknesses of 3 feet. However, contamination can easily travel through thinner sandstone intervals.

8. The top of bedrock topography plays an important role in migration pathways of contaminants. With seismic, we should be able to locate bedrock valleys and their orientation. Therefore the direction of our contaminants may be predicted in the surfical materials as well.

The seismic survey would provide valuable subsurface information. By knowing the extent of the sandstones the determination of the extent of contamination is much more predictable, more precise and cheaper. The cost proposal was provided as a range because of the way the project's scope of work was designed. The scope consists of three tasks, of which Tasks 1 and 2 total $492,000. These two tasks determine the optimum acquisition parameters needed to meet the objectives of the investigations. Task 3, which is dependent upon the findings of Tasks 1 and 2, will range from $300,000 to $1,200,000. Therefore the total cost of the seismic survey would cost from $792,000 to $1,692,000.

Additional drilling is the needed in order to delineate the extent of contamination. The location and depths of specific target intervals would be known thereby reducing the number of wells and time for completion of the program. It is assumed that two small phases will be necessary in order to complete the bedrock investigations (20 wells per phase). With the addition of 40 bedrock wells ($280k to $320k) the cost of implementing and completing the bedrock investigations using high resolution seismic reflection would range from $1.1m to $2.0m in 1.5 years. Using the same assumptions for a monetary equivalent program; installing 178 wells, 150 feet apart, and installing 40 wells per year would take 4.5 years to complete and would not adequately characterize the bedrock.

In summary the programs become cost equivalent when drilling 150 foot centers (178 wells) in the investigation area. This lay-out will not meet the RI objectives. The ultimate question is "what is needed to technically solve the problem and satisfy Rockwell, DOE and the regulating agencies ? "

The advantages of implementing the seismic survey are:

- twice as fast for the equivalent amount of spatial coverage.
- provide the most detailed information possible.
- enable precise well placements.
- decrease the number of wells needed for monitoring purposes.
- decrease the amount of money and time spent on analytical services.
- provide comprehensive data for the proper design of the remedial action.
- Able to map the top of the bedrock surface.

The following is a summary cost comparison between RI programs with and without use of a seismic reflection survey. The drilling program uses 50 foot centers. This is a more reasonable well spread for an adequate characterization, given the existing geology setting. Also presented is the number and spatial distribution of wells for a cost equivalent program.

Seismic Survey	Maximum Cost	$1,692,000
Drilling 40 additional wells	Maximum Cost	$320,000
Analytical Services for one year		$200,000
1.5 years for implementation		
	TOTAL COST	$2.2 million

Drilling 50 foot centers (1,600 wells)	Maximum Cost	$12.8 m
Analytical Services for one year		$7.5 m
40 years for implementation		
	TOTAL COST	$20.3 million

Drilling 150 foot centers	Maximum Cost	$1,424,000
Analytical services for one year		$854,000
4.5 years for implementation		
~180 wells	TOTAL COST	$2.3 million

The amount of detail which is needed is expensive for any of the program's options. It will not be known exactly how much detail is needed to solve the RI until it is nearly finished. The regulating agencies as well Rockwell will not be satisfied until the sandstone bodies are fully characterized. Therefore, it is in my opinion to go with the seismic survey in order to collect the most comprehensive data possible while increasing the efficiency and speed of the program in a cost effective manner.

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